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Floristic composition and management of cropland agroforest in southwestern Bangladesh

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Abstract: Cropland agroforest is an important production system in the southwest region of Bangladesh. This study focused on the floristic composition and management of existing cropland agroforests. A total of 313 cropland agroforests were surveyed and 83% respondents practiced pure agroforestry while the remaining 17% practiced agroforestry with fisheries. A total of 18 forest trees and 2 shrubs were recorded from 11 families and 59 species of agricultural crops were from 28 families. A higher proportion (79%) of cropland agroforests were occupied small land areas (0.12–0.80 ha). About 63% of respondents planted trees for fruit production and 47% for timber production, and 35% of respondents engaged in commercial production (35%). *Swietenia macrophylla* was the most prevalent species (relative prevalence 20.83) followed by *Mangifera indica* (relative prevalence 15.57) and *Cocos nucifera* (relative prevalence 7.08). Shorter spacing was used for timber and fuel wood species and wider spacing for fruit trees. A wide range of rotation periods, from 5 to 25 years, was observed for both cases. The use of chemical fertilizer was highest followed by cow dung and compost in cropland agroforests. Overall management practices of cropland agroforest in southwest Bangladesh were determined by the end product and local demand.

Keywords: agroforestry, Bangladesh, cropland, fruit production, timber production

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Introduction

Agroforestry involves introduction and retention of trees along with cultivation of agricultural crops on a parcel of land. This land management system satisfies the socio-economic needs of people in a sustainable way (Dwivedi 1992; Raintree 1997; Beetz 2011). Numerous ecological and environmental services (protection of crops, livestock, soil and watercourses; biodiversity conservation; diversification of income sources; increased biological production; improved water quality and improved habitat for humans and wildlife) are provided by well designed agroforestry systems. Moreover, agroforestry practices also contribute to carbon sequestration and mitigate climate change effects (Dwivedi 1992; Ahmed 2001; Ahmed et al. 2004). Bangladesh is densely populated with about 80% of the population occupying rural areas (BBS 2011). Two-thirds of the total land area of Bangladesh is arable but per capita availability of arable land is only 0.045 hectare which puts extreme pressure on land for habitation, agriculture and other uses including forestry (Zashimuddin 2004; Ericksen et al. 1997). Agriculture scientists recommend a well-planned and well managed multi-layered cropping system to achieve highest returns from limited amounts of arable land. The vertical distribution of yields in croplands through agroforestry is believed to play a great role in overall improvement in agricultural and forestry production in Bangladesh (Ahmed and Ali 1993). Agroforestry policies were officially initiated during the latter part of 1970 and gained popularity during the last couple of decades (Rahman et al. 2011). Cropland agroforestry practice is, however, a relatively a new idea and is only recently adopted in some areas of Bangladesh. Cropland agroforest includes planting of trees and protecting naturally growing trees in the crop lands (Abedin and Quddus 1990a; Roy 1997; Ahmed 2001) along the margins of smaller crop fields and sometimes within the larger crop fields (Roy 1997). Various vegetables, pulses, cereal crops, and cash crops are cultivated at the early stages and shade tolerant crop species are usually cultivated after 10 to 15 years (Chowdhury 1997).

Azadirachta indica, *Melia azadirachta*, *Eucalyptus* spp., *Artocarpus heterophyllus*, *Ziziphus* spp., *Cocos nucifera*, *Syzygium* spp. *Mangifera indica*, *Dalbergia sissoo*, *Swietenia macrophylla*, *Albizia* spp. *Leucaena leucocephala*, *Litchi chinensis* and *Acacia* spp. are commonly planted in agroforestry plots in Bangladesh without much consideration for productivity, sustainability, environmental conservation, land suitability or local demand (Quddus 2001; Hasanuzzaman et al. 2006; Zaman et al. 2010a). Appropriate selection of tree species and management regimes are, however, key concerns for fulfillment of local market demand and achievement of environmental sustainability in any agroforestry project. Information on types of agroforestry or homestead agroforestry is available in Bangladesh but information on cropland agroforestry is limited. Moreover, there is almost no information on cropland agroforests in southwestern Bangladesh. The present study was aimed to provide information about existing cropland agroforests, particularly their vegetation and management practices. This will help researchers and developers to devise interventions aimed at increased productivity, sustainability and environmental conservation.

Materials and methods

Location of the study area

Three districts (administrative units) e.g. Khulna, Jessore and Satkhira were selected for this study from southwest Bangladesh. These districts (the study area) lie between N 22°44'–23°14'; and E 89°01'–89°36'. Southwest Bangladesh is a low (<10 m asl), flat, and fertile deltaic plain with calcareous to noncalcareous alluvial soils (BBS 2004). A tropical to subtropical monsoon climate characterizes this area. Three distinct seasons are summer (March–May), rainy (June–October), and winter (November–February) and the mean annual rainfall is (1800±268) mm. The mean annual temperature is 26 °C (range: 19–32 °C). In some areas, temperatures drop to 10 °C during winter and reach 40 °C or more during summer (Kabir and Webb 2008).

Sampling procedure

Every district consists of a number of smaller administrative units called sub-districts. Twelve sub-districts (4 sub-districts from each district) were randomly selected for study. In the absence of systematic documented information on cropland agroforests in each sub-district, we selected cropland agroforests in an unbiased manner following Kabir and Webb (2009). Every day a new local guide was hired to assist in selecting cropland agroforests. After selecting the cropland agroforests, the guide was requested to stay away from the agroforests in order to prevent bias with future selection in future days. One hundred cropland agroforests were selected from each of the three districts, Khulna, Jessore and Satkhira. Thus a total of 313 cropland agroforests were selected from the total study area. A semi structured questionnaire was administered to record the response of owners/farmers of the respective cropland agroforests.

Data collection and analysis

Information was collected on the biophysical, demographic and socioeconomic conditions of the cropland agroforest practitioners using a semi-structured questionnaire. The collected information was also supplemented with time-to-time focus group discussions and physical observations of the cropland agroforests. Plant species (trees, shrubs and agricultural crops) in each sampled cropland agroforest were identified and recorded. Each recorded plant species was classified by family, types (trees, shrubs, herbs, and climbers) according to morphology, domesticity (planted/natural), origin, stratum, and common uses. Information on cropland agroforest management practices was also collected that covered major aspects of management practices such as planting material/seedling quality, spacing, tending, irrigation and fertilization, pest and disease control and rotation of tree species. Statistical analysis (multiple response and descriptive statistics) was performed using SPSS (11.5) statistical software. Moreover, relative prevalence (R_p) of different tree species was determined by the following equation.

$$R_p = (N / C) \times \text{Cropland with specimen species (\%)} \quad \text{(Chowdhury 1997)} \quad (1)$$

where, R_p is the relative prevalence; N is number of trees; C is the area of croplands.

Results and discussion

Demographic and socio-economic characteristics of the respondents

The age range of the respondents was 18–70 years. Respondents were classified into three age categories; young (<18 years old), middle age (19–50 years old) and elderly (>50 years old). The average age of the respondents was 44 years. Most respondents (66%) were middle aged, followed by elderly (32%) and young (18%). Zaman et al. (2010b) reported the average age of agroforest farmers was 32 years and the majority (71%) was from the middle aged category in northern Bangladesh. Most farmers (about 53%) were middle aged in homestead agroforestry in southwestern Bangladesh (Kabir and Webb 2009). This comparison reveals that middle aged people were more engaged in agroforestry activities. The levels of education among the farmers were categorized into five groups. The proportions of educational level of the respondents were 18%, 44%, 20%, 14% and 4% for illiterate (no schooling), primary level (1 to 5 years of schooling), secondary level (6 to 10 years of schooling), higher secondary level (10 to 12 years of schooling) and higher study (16 years and above), respectively. The occupations of respondents were classified into five major groups i.e. farmer, fisherman, business, service and student and the proportions were 74%, 10%, 8%, 5% and 3%, respectively. Similar observation on education-

al level was reported for northern Bangladesh, where a higher proportion (49%) of respondents had primary education (Zaman et al. 2010a). Kabir and Webb (2009) and Zaman et al. (2010a) reported that agriculture was the main occupation of the agroforest farmers in southwestern and northern Bangladesh.

Cropland agroforest hectarage

The cropland area was categorized as marginal (below 0.12 ha), small (0.12–0.80 ha), medium (0.80–2.0 ha) and large (above 2.0 ha) in southwestern Bangladesh. About 53% and 58% of homestead agroforests were found to occur on small land areas in northern and southwestern Bangladesh respectively (Kabir and Webb 2009; Zaman et al. 2010b). However, we found a higher proportion (79%) of cropland agroforest occupied the small land areas (0.12–0.80 ha) (Table 1).

Table 1: Size of cropland agroforests in southwestern Bangladesh

Size of cropland agroforests	Area (ha)	Respondent (%)
Below	0.12	15
Small	0.12-0.80	78.6
Medium	0.80-2.0	5.4
Large	Above 2.0	1

This is a common phenomenon in Bangladesh, where the large population has small land holdings (average farm size, 0.80 ha) for cultivation as well as dwelling (Hocking and Islam 1994). Almost all respondents (99%) started cropland agroforestry from self-motivation and very few farmers (0.36%) received technical support (selection of tree and agricultural crops) from Union councils or other organizations. Chowdhury (1997) reported that most farmers did not receive motivational or technical assistance from governmental or non-governmental organizations. Quddus (2001) reported that small cropland holders preferred planting trees along the field boundaries. But we recorded no differences in planting trees on the boundaries of all categories of cropland agroforests in our study area. Fruit and timber species were common to all cropland agroforest plot sizes but medium cropland holders planted fuel and fodder species in addition to fruit and timber species, and these differences were prominent in our study area.

Structure and composition of cropland agroforests

People plant trees on all possible types of land in southwest Bangladesh i.e. in croplands and on the boundaries of shrimp/fish culture areas. Mostly two types of cropland agroforestry practices i.e., pure agroforestry (83%) and agroforestry with fisheries (17%) were found in the study area. About 63% of respondents planted trees for fruit production and 47% planted trees for timber, and 35% of respondents tended commercial plots (Table 2). These results are similar to those reported by Kamaluddin (1997) and Khaleque (1987). Farmers plant various fruit tree species for their multipurpose nature (Abedin and Quddus 1990b; Chowdhury 1997). Besides fruit trees, about 18% of cropland agroforest farmers was planted fuel wood trees in southwestern Bangladesh (Table 2). Chowdhury (1997) found that 15% of farmers planted trees for fuel wood production in the croplands of Bangladesh. People planted trees in our study area for other purposes such as hedgerow fence, boundary demarcation, raw material supply to various wood based industries and some extraordinary uses (Table 2), similar to the findings of Chowdhury (1997).

Table 2: Purposes of tree plantation in cropland agroforests in southwestern Bangladesh

Types	Respondent (%)
Fruit production	62.9
Timber production	46.6
Commercial business	35.1
Fuel wood production	18.5
Easy to take care	8.6
Fodder production	2.6
Boundary mark	2.6
Industrial use	1.0

Note: Results are multiple responses from the respondents.

Trees in the cropland agroforests

A total of 18 tree species and 2 shrubs (10 native and 10 exotic species) were identified from 11 families. Fabaceae, Meliaceae and Palmae accounted for the highest number of species in the cropland agroforests of southwestern Bangladesh. Kabir and Webb (2008) recorded a total of 146 tree species in the homesteads of southwestern Bangladesh, Uddin et al. (2002) recorded 35 tree species in the southeast, Zaman et al. (2010b) recorded 62 tree species in the north and Ahmed et al. (2004) recorded 39 tree species in central Bangladesh. The differences are probably due to the primary products expected from the cropland agroforests and the species that can grow without sacrificing much of the crop yield. This could be the reason for observing smaller number of tree species in the cropland agroforests compared to other agroforestry/homestead forest (Chowdhury 1997). Among the trees and shrubs, Mahogany (*Swietenia macrophylla)*, Mango (*Mangifera indica*), Coconut (*Cocos nucifera)*, Date (*Phoenix sylvestris*), Palm (*Borassus flabellifer)*, Plum (*Ziziphus* spp.), Litchi (*Litchi chinensis*), Bettle-nut (*Areca catechu*) and Lemon (*Citrus limon*) were identified as major species with relative prevalence (R_P) ranging from 20.83 to 1.17. *Swietenia macrophylla* was the most prevalent species (R_P =20.83) in cropland agroforests in southwest Bangladesh (Table 3). Regionally, *Artocarpus heterophyllus* (R_P =26.28) in central Bangladesh, *Mangifera indica* (R_P =32.58) in northern Bangladesh and *Areca catechu* (R_P = 6.15) in various homesteads of Bangladesh are the most prevalent species (Ahmed et al. 2004; Chowdhury 1997; Zaman et al. 2010a). About 57% of cropland agroforest farmers in our study area preferred *Swietenia macrophylla* for timber production because of its high market value of timber, small crown with thin branches, straight single stem with a long clear

bole, and fast growing characteristics (Mayhew and Newton 1998).

Table 3: Relative prevalence and preference of available tree species in cropland agroforests of southwestern Bangladesh

English name	Botanical name	Family	Types	Origin	Relative prevalence
Mahogany	*Swietenia macrophylla*	Meliaceae	Tree	Exotic	20.83
Mango	*Mangifera indica*	Anacardiaceae	Tree	Native	15.57
Coconut	*Cocos nucifera*	Palmae	Tree	Native	7.08
Plum	*Ziziphus spp.*	Rhamnaceae	Shrub	Native	4.14
Bettle-nut	*Areca catechu*	Arecaceae	Tree	Native	2.74
Date	*Phoenix sylvestris*	Palmae	Tree	Native	1.92
Lemon	*Citrus limon*	Rutaceae	Shrub	Native	1.76
Palm	*Borassus flabellifer*	Palmae	Tree	Native	1.19
Litchi	*Litchi chinensis*	Sapindaceae	Tree	Native	1.17
Shirish	*Albizia saman*	Leguminosae	Tree	Exotic	0.77
Lombu	*Khaya anthotheca*	Meliaceae	Tree	Exotic	0.63
Ghora neem	*Melia azadirachta*	Meliaceae	Tree	Exotic	0.46
Jackfruit	*Artocarpus heteropryllus*	Moraceae	Tree	Exotic	0.29
Neem	*Azadirachta indica*	Meliaceae	Tree	Native	0.26
Akashmoni	*Acacia auriculiformis*	Fabaceae	Tree	Exotic	0.10
Ipil-ipil	*Leucaena leucocephala*	Fabaceae	Tree	Exotic	0.06
Eucalyptus	*Eucalyptus camaldulensis*	Myrtaceae	Tree	Exotic	0.03
Chambal	*Albizia rechardiana*	Fabaceae	Tree	Exotic	0.03
Sissoo	*Dalbergia sissoo*	Fabaceae	Tree	Exotic	0.03
Babla	*Acacia nilotica*	Leguminosae	Tree	Native	0.02

This species can grow in a range of soil types, including alluvial soils, heavy clays, and lateritic soils (Lamprecht 1989). Neem (*Azadirachta indica*), Ghora neem (*Melia azadirachta*) and Lombu (*Khaya anthotheca*) were also planted as timber species but a small number of respondents (1.0%) preferred Akashmoni (*Acacia auriculiformis*), Sissoo (*Dalbergia sissoo*) and Eucalyptus (*Eucalyptus camaldulensis*) as timber species in our study area (Table 3). *Eucalyptus camaldulencis* was the most common timber species in northern Bangladesh (Ahmed 2001). Nine fruit tree species were identified in the croplands of the study area. Many respondents (41%) planted *Mangifera indica* as a fruit tree followed by *Cocos nucifera* (26%), *Phoenix sylvestris* (24%), *Ziziphus* spp. (11%) and *Areca catechu* (7%), (Table 3). Fruit trees are the most common tree species in the croplands and homesteads of Bangladesh and *Mangifera indica* is the dominant species in every agroforestry practices in every region of Bangladesh (Chowdhury 1997; Millat-e-Mustafa et al. 1996; Kamaluddin 1997). Other species such as, Plum (*Ziziphus* spp.), Litchi (*Litchi chinensis*), Jackfruit (*Artocarpus heterophyllus*), Coconut (*Cocos nucifera*), Date (*Phoenix sylvestris*), Palm (*Borassus flabellifer*) and Bettle-nut (*Areca catechu*) were also found as fruit trees. The mixture of several tree species is more frequent than monoculture in the crop fields of southwest Bangladesh (Chowdhury and Satter 1992). Only four tree species were used as fuel wood among the identified 18 tree species in the cropland agroforests of our study area. Most of the respondents planted *Albizia saman* for fuel wood but, *Leucaena leucocephala*, *Albizia rechardiana* and *Acacia nilotica* were also recorded as fuel wood species (Table 3). Farmers planted trees in their croplands to get additional benefits other than agricultural crops, including increased income, supply of fuel wood, timber, construction materials; control of soil erosion and insurance against risk of crop failure (Chowdhury 1997). Almost all respondents (90%) of our study area commented that gross household income increased due to practice of cropland agroforestry. Crop yields decline, however, when trees are grown to full size (Chowdhury and Satter 1992).

Agricultural crops

We identified a total of 59 agricultural crops of 28 families. Cucurbitaceae, Leguminosae, Solanaceae and Graminae contained the highest numbers of crop species. However, 40 agricultural crops were identified in the southeast and 32 agricultural crops in the north and central parts of Bangladesh (Uddin et al. 2002; Zaman et al. 2010b; Ahmed et al. 2004). We recorded a higher number of agricultural crops in southwest Bangladesh than reported for other areas. All the agricultural crops with their botanical and family names are listed in Appendix 1. The most common vegetables that were grown in association with trees in the study area were arum (*Colocasia esculenta*), potato (*Solanum tuberosum*), cauliflower (*Brassica botrytis*), cabbage (*Brassica capitata*), brinjal (*Solanum melongena*), parble (*Trichosanthes dioica*), bean (*Lablab niger*), pumpkin (*Cucurbita maxima*), lentil (*Lens culinaris*) and turmeric (*Curcuma longa*). However, most of these are common crops of Bangladesh (Chowdhury 1997). Turmeric is common as a year round crop in this region particularly in the fields where tree density is relatively high, as reported by Chowdhury (1997). In kharif season (April-September) *Oryzae sativa*, *Corchorus capsularis*, *Sesamum indicum* and in rabi season (October-March) *Lens culinaris*, *Brassica campestris*, *Triticum aestivum* and others are

grown on a large scale in the study sites. Papaya (*Carica papaya*) and Banana (*Musa* spp.) is common year round crop of cropland agroforests of southwestern Bangladesh. The agricultural crops can be classified as minor and major crops depending on the level of availability. Among the agricultural crops, 43 species were identified as minor crops and 16 species as major crops. Agricultural crops (minor and major) with their associations are listed in Table 4. Tree and agricultural crop combinations in cropland agroforests were much higher than in traditional farming. The diversity of agricultural crops (cereal crops, cash crops, under ground and above ground vegetables, leafy vegetables, climbers, pulses, spices, flowers and annuals/perennials) in the cropland agroforests is higher than in homestead agroforesty practices where the agricultural crops are typically limited to vegetables, climbers and spices (Ahmed et al. 2004; Zaman et al. 2010a; Zaman et al. 2010b).

Table 4: Tree - crop combination in cropland agroforests in southwest Bangladesh

Trees	Major agricultural crops	Minor agricultural crops
Mahogany	Paddy, Jute, Sesame, Arum, Potato, Cauliflower, Cabbage, Brinjal, Parble, Bean, Pumpkin, Lentil, Mustard, Turmeric, Papaya, Banana, Bottle gourd	Pumpkin, Elephant foot yam, Tomato, Kohlrabi, Lady's finger, Red leafy, Amaranph, Basil, Balsam apple, Mung bean, Green peeper, Onion, Aniseed
Mango	Paddy, Jute, Sesame, Potato, Cauliflower, Cabbage, Brinjal, Bean, Papaya, Banana	Arum, Lady's finger, Kohlrabi, Red leafy, Bottle gourd, Parble, Lentil, Mustard
Coconut	Paddy, Banana, Sesame, Papaya	Jute, Arum, Potato , Cauliflower, Cabbage
Date	Paddy, Jute, Lentil, Papaya, Banana	Sesame, Arum, Potato, Cauliflower, Brinjal
Plum	Turmeric, Green peeper, Cauliflower	Paddy, Brinjal, Papaya, Banana
Litchi	Sesame, Lentil	Green peeper, Papaya, Garlic
Jackfruit	Lentil	Paddy, Banana, Jute, Papaya
Neem	Paddy	Cabbage, Papaya, Brinjal, Parble, Banana
Ghora neem	-	Brinjal, Jute, Cauliflower, Paddy, Papaya
Palm	-	Jute, Paddy, Banana, Brinjal
Shirish	-	Basil, Sesame, Banana, Jute, Paddy, Brinjal
Lombu	-	Sesame, Brinjal, Papaya
Bettle-nut	-	Paddy, Banana, Lentil, Banana, Bettle leaf
Lemon	-	Banana, Papaya, Mustard, Papaya, Paddy
Akashmoni	-	Potato, Turmeric
Eucalyptus	-	Lady's finger, Pumpkin
Ipil-ipil	-	Paddy, Red leafy, Bean
Chambal	-	Arum, Paddy
Sissoo	-	Brinjal, Paddy, Kohlrabi
Babla	-	Cauliflower, Cabbage

Management of cropland agroforest

Planting materials and spacing

Most respondents (61%) bought seedlings from the local nursery and the remainder (38%) produced seedlings on their own land. Union councils provided seedlings to the farmers in a negligible amount (1.0%). Almost all the farmers like to plant good quality seedlings or planting materials for fruit tree species but they were less concerned about good quality planting material for timber and fuel wood species. Moreover, the cropland agroforestry practitioners preferred to plant more mature seedlings, especially for fruit trees to get early fruiting. Lower spacing (3/3, 4/4 and 6/6 m) was observed for timber and fuel wood species, with wider spacing (3/3, 4/4, 6/6, 8/8, 8/12, 12/12, 12/15 and 15/15 m) for fruit trees. Wider spacing was also observed for mixtures of fruit and timber/fuel wood trees. Eighty-two percent of respondents maintained spacing between trees to reduce the competition for light, moisture and nutrients. Hocking and Islam (1994) noted that farmers should use wide spacing of trees at least 8 m from tree to tree and plant mainly along aisles and within a field only when fields are wider than 16 m to minimize the loss of crop production.

Tending operation

Tending operations such as pruning, thinning, weeding was conducted by cropland agroforest practitioners. Pollarding was conducted annually for *Zizyphus jujube*. Pruning was also conducted in alternate years or at several year intervals for some timber trees and some farmers stopped pruning when trees became tall. Fruit trees were not thinned by the respondents. Pruned materials (small braches, twigs, leaves) were used as fuel (Table 5). Various pruned materials are used as fuel by the villagers of Bangladesh (Hocking and Islam 1994). Weeding was carried out in August-October in our study area, similar to the report of Hasan et al. (2008). Although the fallen leaves of trees, crop residues and weeds are often removed from the croplands, they can provide nutrients to crops (Chowdhury 1997; Hossain et

al. 1988). Few cropland holders in our study area know of this but most respondents (90.7%) use leaf litter as fuel (Table 5).

Table 5: Types of fuel and fertilizaer used by the farmers of cropland agroforest

Types of fuel	Respondent (%)	Types of fertilizer	Respondent (%)
Leaf litter	90.7	Chemical fertilizer	99.7
Cow dung	75.2	Cow dung	82.4
Pruned branch	57.3	Compost	11.5
Agricultural residue	35.4	Green manure	3.5
Bamboo	18.4		

Note: Results are multiple responses from the respondents.

Irrigation and fertilization

Respondents used different fertilizers to enhance the productivity of their crops. Almost all respondents applied chemical fertilizer (99.7%) and cow dung (82.4%) to their cropland agroforest. A few respondents (11.5%) used compost and a smaller number of respondents (3.5%) used of leaf litter as manure (Table 5). Conversely, they did not apply fertilizer or irrigation for the timber and fuel wood producing tree species.

Pest and disease control

Almost all respondents (99.3%) used pesticides and insecticides on their agricultural crops and fruit trees for better production. Many respondents had received no training and had no proper knowledge on the application of different pesticides and insecticides. However, Robbani et al. (2007) reported that the use of pesticides and insecticides is increasing which impacts the land productivity as well as the habitats of some beneficial insects.

Rotation

Rotation ages for timber and fruit tree species ranged from 5 to 25 years, while fuel wood trees were rotated at 5−15 years. In some cases, different rotation periods for a single tree species were followed, depending on the end product (fruit, timber or fuel wood). Sometimes, respondents used different rotations for different varieties of a single tree species i.e. *Mangifera indica* was found to maintain a wide range of rotation period from 7−25 years (Table 6). We observed longer rotation periods for trees in croplands, mainly for fruit trees, whereas Quddus (2001) reported short rotations in the croplands from 7−13 years in northwest Bangladesh.

Table 6: Rotation and uses of different tree species in the cropland agroforest of southwest Bangladesh

Name of Species	Rotation period			Uses
	Minimum	Maximum	Average	
Mangifera indica	7	25	17	Fruit, timber, fuel, fodder
Artocarpus heterophyllus	15	24	21	Fruit, timber, fodder
Zizyphus spp.	13	20	17	Fruit, fuel, fodder
Litchi chinensis	13	22	18	Fruit
Cocos nucifera	Not fixed	Not fixed	Not fixed	Fruit, fuel, construction
Phoenix sylvestris	Not fixed	Not fixed	Not fixed	Fruit, fuel
Borassus flabellifer	Not fixed	Not fixed	Not fixed	Fruit, fuel, construction
Areca catechu	Not fixed	Not fixed	Not fixed	Fruit, fuel, construction, boundary
Citrus limon	Not fixed	Not fixed	Not fixed	Fruit, fuel, fence, boundary
Swietenia macrophylla	10	20	16	Timber, furniture, construction
Dalbergia sissoo	12	19	16	Timber, furniture
Melia azadirachta	11	17	14	Timber, fuel
Acacia auriculiformis	8	16	13	Timber
Khaya anthotheca	9	16	13	Timber, industrial use
Eucalyptus camaldulensis	7	15	13	Paper and pulp, pole, timber
Azadirachta indica	14	21	17	Timber, construction, medicinal
Albizia saman	6	13	8	Fuel, timber, fuel
Albizia rechardiana	6	13	11	Fuel, timber
Acacia nilotica	7	15	12	Fuel, timber, fodder
Leucaena leucocephala	5	14	9	Fodder, fuel, timber

Problems in practicing cropland agroforestry

Pest and insect attack were the major problems, followed by cattle, shade and root competition in cropland agroforestry in southwest Bangladesh. A small portion of the respondents also identified theft, flood and leaf toxicity as problems (Table 7). A small proportion (15.4%) of respondents reported less production in their cropland agroforests than in traditional farming. Chowdhury and Satter (1992) reported that crop yields declined when trees were grown in association with crops.

Table 7: Problems of practicing cropland agroforestry in southwest Bangladesh

Types	Respondent (%)
Pest and insect attack	57.3
Cattle	43.4
Shade	34.9
Root competition	22.2
Theft	19.8
Flood	17.1
Less production	15.4
Leaf toxicity	4.5
No problem	14.5

Note: Results are multiple responses from the respondents.

Conclusion

The practice of cropland agroforestry started in southwest Bangladesh from the initiative of local people who continue to develop agroforestry through self motivation.

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Appendix 1: List of agricultural crops in the cropland agroforests in southwestern Bangladesh

Types	English name	Scientific name	Family	Types	English name	Scientific name	Family
Cereal crops	Paddy	*Oryzae sativa*	Graminae	Climber vegetables	Pumpkin	*Cucurbita maxima*	Cucurbitaceae
	Wheat	*Triticum aestivum*	Poaceae		Balsam apple	*Momordica charantia*	Cucurbitaceae
	Maize	*Zea mays*	Poaceae		Ridge gourd	*Luffa cylindrica*	Cucurbitaceae
Cash crops	Jute	*Corchorus capsularis*	Tiliaceae		Cucumber	*Cucumis sativus*	Cucurbitaceae
	Sesame	*Sesamum indicum*	Pedaliaceae		Green cucumber	*Benincasa hispida*	Cucurbitaceae
	Sugarcane	*Saccharum officinarum*	Poaceae		Sweet bitter gourd	*Momordica cochinchinensis*	Cucurbitaceae
	Cotton	*Gossypium herbaceum*	Malvaceae		Asparagus bean	*Vigna unguicalata*	Leguminosae
	Mustard	*Brassica campestris*	Brassicaceae		Snake gourd	*Trichosanthes anguina*	Cucurbitaceae
Under ground vegetables	Potato	*Solanum tuberosum*	Solanaceae	Pulses	Lentil	*Lens culinaris*	Leguminosae
	Arum	*Colocasia esculenta*	Araceae		Mung bean	*Vigna radiata*	Leguminosae
	Arum(Man Kachu)	*Alocasia indica*	Araceae		Green pea	*Pisum sativum*	Leguminosae
	Elephant foot yam	*Amorphophallus campanulatus*	Araceae		Grass pea	*Lathyrus sativum*	Leguminosae
	Mud potato	*Dioscorea alata*	Dioscoreaceae	Spices	Green peeper	*Capsicum frutescens*	Solanaceae
	Carrot	*Daucus carota*	Umbelliferae		Turmeric	*Curcuma longa*	Zingiberaceae
	Radish	*Raphanus sativus*	Cruciferae		Onion	*Alium cepa*	Liliaceae
	Turnip	*Brassica campestris*	Cruciferae		Garlic	*Allium sativum*	Liliaceae
Above ground vegetables	Brinjal	*Solanum melongena*	Solanaceae		Aniseed	*Foeniculum vulgare*	Umbelliferae
	Cabbage	*Brassica capitata*	Brassicaceae		Coriander	*Coriandrum sativum*	Umbelliferae
	Cauliflower	*Brassica botrytis*	Brassicaceae		Ginger	*Zingiber officinale*	Zingiberaceae
	Lady's finger	*Abelmoschus esculentus*	Malvaceae	Flowers	Rose	*Rosa centifolia*	Rosaceae
	Tomato	*Lycopersicon esculentum*	Solanaceae		Gladiolus	*Gladiolus spp.*	Iridaceae
	Kohlrabi	*Brassica gongyloides*	Brassicaceae		Marie gold	*Tagetes patula*	Compositae
Leafy vegetables	Red leafy	*Amaranthus tricolor*	Amaranthaceae		Gerbera	*Gerbera aurantiaca*	Asteraceae
	Amaranph	*Amaranthus lividus*	Amaranthaceae		Tube rose	*Polianthes tuberosa*	Amaryllidaceae
	Basil	*Basella alba*	Basellaceae	Annuals /Perennials	Banana	*Musa spp.*	Musaceae
	Spinach	*Spinacea oleraceae*	Chenopodiaceae		Papaya	*Carica papaya*	Caricaceae
Climber vegetables	Bean	*Lablab niger*	Leguminosae		Bettle-leaf	*Piper betel*	Piperaceae
	Parble	*Trichosanthes dioica*	Cucurbitaceae		Drum stick	*Moringa oleifera*	Moringaceae
	Bottle gourd	*Lagenaria siceraria*	Cucurbitaceae				